Memorandum

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To: Diboro Kanabolo - 08
Design "O"

Attn: Fred Asef

Date: Sept. 13, 2012

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From: **DEPARTMENT OF TRANSPORTATION**
Division of Engineering Services
Office of Geotechnical Design South - 2

Subject: Geotechnical Design Report for Retaining Walls

Per your request dated June 7, 2012, our Office completed a site investigation and prepared this report. The proposed project is to widen the SR 138 roadway from two lanes to four lanes with a four-foot buffer. This report addresses all of the proposed nineteen retaining walls.

Previous reports submitted for this project include: "Geotechnical Design Report for Converting the Existing Two-Lane Highway to a Four-Lane with a median Left-Turn Lane on SR 138", Sept. 2002, by OGDS2 (includes a Seismic Refraction Report for the Mormon Rocks area PM 13.8); and "Geotechnical Design Report for Retaining Walls PM 14.5", May 14, 2009, by OGDS2. These reports are comprehensive and still valid.

General Geology

The San Bernardino Mountains rise steeply north of the city of San Bernardino. The Antelope Highway lies within the Cajon Basin west of Cajon Pass, the natural pass separating the San Gabriel Mountains from the San Bernardino Mountains. This portion also lies southwesterly and roughly parallel to the flow line of Cajon Canyon, which is also located just beyond the base of Lone Pine Ridge to the southwest. Lone Pine Ridge, underlain by Mesozoic plutonic rock and pre-Mesozoic gneiss and marble, separates Cajon Canyon from Lone Pine Canyon on the southwest. The San Andreas Fault to the southwest of the highway, trends west-northwest through the Transverse Ranges, lies within Lone Pine Canyon. The Cleghorn-North Frontal Fault system lies to the east of the project.

The geologic terrane through which these walls will stand has been mapped as Quaternary Shoemaker Gravel (deposits are mapped as well dissected alluvial fan deposits), Tertiary Crowder Formation Sandstone, and Punchbowl Sandstone.

As shown on the California Seismic Hazard Map of 1996, the controlling fault to the project site is the Cleghorn-North Frontal Fault, a reverse-thrust fault thought capable of generating a Magnitude 7.75 event. That fault is 1.2 miles from the eastern alignment of Route 138. As such, it is unlikely that surface rupture will cause significant horizontal and vertical surface displacement at the site. We anticipate the project area could experience peak bedrock accelerations of up to 0.7g.

The weather is arid in the summer but winter can produce **freeze/thaw conditions** from snowfall. Rains can be torrential and rain-on-snow events can bring down much surface material.

Site Characteristics

The Phase 1 project area has a topographic high elevation of about 4800 ft. at PM 6.7 called "Mountain Top", where Hwy. 2 intersects Hwy. 138. The terrain on which Hwy. 138 travels is formational, unconsolidated SANDS with interbedded thin gravels and minor silty sand layers. The material is in a medium dense to very dense condition. This material underlies the Mojave Desert and has been slightly uplifted adjacent to the zone of the San Andreas Fault. It is the North American Plate boundary.

To the north of Mountain Top, the Highway descends along Horse Canyon to Sheep Creek Bridge (PM 3.6) where it enters the relatively flat Mojave Desert (elevation 4300 ft. at PM 2.9). To the south of Mountain Top, Cajon Canyon (a dry wash) travels adjacent to the highway with several formational outliers bisected that were more resistant to erosion. The highway also bisects the "Mormon Rocks" terrane, a hard, resistant SANDSTONE with minor discontinuous gravel layers. The project ends at the alluvial (sands and gravels) intersection of Cajon Canyon and Cajon Creek at I-15 (elevation 3140 ft. at PM 15.1).

Site Investigation

Our Office conducted a site sub-surface investigation which consisted of eight vertical auger borings to a maximum depth of 50.5 feet. We also drilled two horizontal boring to 43 ft. in length. Previous borings include four auger borings to a maximum depth of 51.5 ft. at PM 14.5 and several borings for the bridge sites where retaining walls are proposed. The LOTB's for these borings will be sent at a later time when completed.

The predominant material recovered from the borings consists of SAND with gravel (to boulder size as seen on the surface) and silty sand in a dry, medium dense to very dense condition. The material generally becomes less silty and more gravelly with greater depth and to a denser condition.

The potential for liquefaction is not anticipated based on groundwater depth and generally dense nature of the subsurface granular soils. Groundwater was encountered in borings at PM 14.5 to 14.6, with depth of 49 to 40 ft. below the ground surface respectively (shallowing towards Cajon Creek) with dry weather conditions. Water levels will fluctuate with rainfall events but should not affect construction.

Corrosion

The Materials Engineering and Testing Services, Testing and Technology Branch, has performed corrosion tests CTM 417, 422, and 643 on soil samples from the field investigation. Laboratory test results from boring samples indicate that soils at the site are considered **non-corrosive** except **at boring A-08-102** where it is **corrosive** for high chlorides. Additional corrosion tests are presented in the 2002 GDR. See Table 1 below.

Table 1: Corrosion Test Summary

Boring	Sample Depth	Sample Date	PH	Minimum Resistivity (ohm-cm)	Sulfate Content (PPM)	Chloride Content (PPM)
A-08-101	5-10 feet	9/23/2008	8.13	7259	N/A	N/A
A-08-102	5-10 feet	9/24/2008	8.14	574	39	808
A-09-101	5-10 feet	3/17/2009	7.92	13628	N/A	N/A
A-09-102	5-10 feet	3/18/2009	8.64	17364	N/A	N/A
A-12-001	5-10 feet	8/28/2012	8.87	3029	N/A	N/A
A-12-003	5-10 feet	8/28/2012	8.42	5575	N/A	N/A
A-12-006	5-10 feet	9/11/2012	8.25	17920	N/A	N/A
A-12-007	10-15 feet	9/12/2012	8.82	10080	N/A	N/A
A-12-008	5-10 feet	9/12/2012	8.33	16838	N/A	N/A

Note: Caltrans currently defines a corrosive area as an area where the soil and/or water contains more than 500 ppm of chlorides, more than 1500 ppm of sulfates, has a minimum resistivity of less than 2000 ohm-centimeters or has a pH of 5.5 or less.

Subsurface Soil Conditions

RW 316 – This wall is for a fill slope between Stations 316+50 and 319+50. Borings A-12-001 and A-12-002 were drilled at both ends of the wall. The material is poorly-graded SAND with gravel and silt to a depth of 7 ft. in A-12-001 and 14 ft in A-12-002 in a medium dense to dense condition. Below these depths is well-graded SAND with gravel and silt in a medium dense to very dense condition.

RW 328 - This wall is for a fill slope between Stations 328+50 and 331+00. Borings A-12-003 applies to this wall. The material is well-graded SAND with gravel and silt in a medium dense to dense condition.

RW 372 - This wall is for a 20 ft. high cut slope between Stations 372+00 and 374+50. Horizontal boring RC-12-010 was drilled at this location. The material is well-graded SAND with gravel and silt in a medium dense to very dense condition. No caving was observed during our drilling operation.

RW 376 – This wall is for a fill slope between Stations 376+00 and 379+00. Borings A-12-004 applies to this wall. The material is SILTY SAND in a very dense condition. The silt content is very high and slakes (breaks down) rapidly in water. This material should not be used as fill material and the wall footing should be protected from any water infiltration. Erosion control should extend for 1 mile on the down-slope side of the roadway prism.

RW 446 - This wall is for a 16 ft. high cut slope between Stations 446+00 and449+00. Horizontal boring RC-12-009 was drilled at this location. The material from the surface to 10 ft. below is a SILTY SAND with GRAVEL in a medium dense to very dense condition. Below that is well-graded SAND with gravel in a medium dense to very dense condition. The boring was left open for twenty-four hours and no caving was observed.

RW 706 & 707 – Between Stations 707+00 to 711+50 is proposed cuts in the Punchbowl Formation (Mormon Rocks) hard SANDSTONE. Bedding dips 45 degrees to the north (See Seismic Refraction Report for the Mormon Rocks at PM 13.8, June 13, 2001).

RW 743 - This wall is for an 8 ft. high cut slope between Stations 743+00 and 748+00 and passes under the Cajon Mount RR. Borings A-12-005 and A-12-006 were drilled at both ends of the wall. The material in boring A-12-005 is well-graded SAND with gravel and silt in a medium dense to dense condition. In boring A-12-006, the material is well-graded SAND with gravel in a medium dense to dense condition to 14 ft. Below that it is SILTY SAND in a dense condition.

RW 751, 752, 755 & 756 – These four walls support new fill on the north side at the Pine Lodge West Bridge Overcrossing, Sta. 750+00 to 756+00. 755 is the tallest fill wall on the project at 34 ft. Boring RC-10-001 shows poorly-graded SAND medium dense to dense condition to 16 ft. below the surface and then SILTY SAND in a medium dense to very dense condition. RC-10-002 shows poorly-graded SAND with SILT in a medium dense to dense condition.

RW 758 – This fill wall is from Sta. 758+50 to 764+00. Boring A-12-008 was drilled for this wall. It is well-graded SAND with GRAVEL in a dense to very dense condition.

RW 763 & 768 – These fill walls were drilled in 2009. Please see GDR for RW at PM 14.5, May 14, 2009 under this EA for conditions for these walls.

RW 775 – This wall supports fill at the Overcrossing at Pine Lodge East from Sta. 775+00 to 778+00. Boring A-12-007 was drilled for wall 775. The material is well-graded SAND with GRAVEL in a medium dense to very dense condition.

RW 780, 781 & 782 – These walls support fill at Pine Lodge East from Sta. 778+00 to 784+00. Boring RC-10-001 is for RW 781 and is poorly-graded SAND in a loose condition to 8.5 ft. then poorly-graded SAND with GRAVEL and COBBLES in a dense condition. Boring RC-10-002 was drilled for RW 780 and 782. The material is poorly-graded SAND with GRAVEL and COBBLES in a very dense condition.

Table 2: Wall Type and Condition

RW	Type	Case Loading	Notes
~~316~~	1	3	See recommendation in next section.
~~328~~	1	3	See recommendation in next section.
372	Soil-Nail		See soil-nail recommendations.
~~376~~	1	3	See recommendations below.
446	Soil-Nail		See soil-nail recommendations.
706 &707			See recommendations below.
743	1	2	
751, 752, 755 &756	1	2	
~~758~~	1	3	
~~763 & 768~~	1	3	For RW 763 see recommendations below.
~~775, 780, 781 & 782~~	1	3	For RW 781 & 782 see recommendations below.

Recommendations for Type 1 Retaining Walls

Based on our visual observations, boring logs, and our analysis, the following recommendations are made:

1) A standard Type 1 wall foundation design is concurred by our office.

2) The foundation for RW 376 should be protected from water infiltration. Install backdrain and appropriate erosion control.

3) For RW 706 & 707 we do **not** recommend retaining walls. We recommend 1:1 cut slope on the south side only. This will require pre-split blasting between Sta. 706+00 and 712+00 and should have a 10 ft. wide catchment area at the toe of slope according to the Ritchie Criteria.

4) The foundation for RW 763 should be protected against tested corrosion potential.

5) For RW 781 and 782, loose sand was encountered during our site investigation near the footing elevation. We recommend the soil underneath the footing bottom to be removed to a minimum of 2 ft below the footing bottom. The overexcavated area should extend at least 2 ft in front of the footing envelope. The overexcavated area should be scarified, recompacted to at least 90% relative compaction. The area can then be backfilled with on-site materials, which should be compacted to at least 95% relative compaction.

6) Any loose material found at the footing bottom, we recommend following the directions of Bullet 5 above.

7) Oversize cobbles and boulders may exist at the footing elevation which should be removed.

8) Erosion protection for all slopes, such as hydroseeding, should be used along with straw

wattles or erosion control mats.

9) A minimum cover of 2.0 ft. of soil on top of the wall footing is recommended. The edge of slope at the hinge point should be at least 2.0 ft. away from the edge of footing.

10) At Boring A-12-009, the horizontal boring was left open for 24 hours. No caving was observed but it should be assumed that caving will occur in the sandy/gravelly soils.

11) Soil parameters of internal friction are 32°, cohesion 0, and a unit weight of 125 psf. The bearing capacity in ksf equals 4 +0.5 B (footing width in ft.) with a Factor of Safety of 3.

Recommendations for Soil-Nail Walls

There are two (2) soil nail walls proposed for this project site. SNAIL program (Version 3.09) was used for analysis and design purpose. No surcharge loading nor traffic loading is assumed on the access roadway above the wall. Ground water is not considered for this case. The soil nail walls are designed generally in accordance with the guidelines provided by FHWA's Manual for Design & Construction Monitoring of Soil Nail Walls, Edition 1996. The recommended design data are as follows:

Table 3: General Design Information for Soil-Nail Walls

Wall Nos.	Stations		Max. Wall Height (ft)	Min. Nail Length (ft)	Spacing (ft)				Design Punch Shear (Kips)	Design Yield Stress (Ksi)
					Vertical			Horiz.		
	From	To			Top	Mid	Bottom			
RW372	372+00	374+50	20.0	H + 5.0	2.5	5.0	1.5	5.0	40.0	60.0
RW446	446+00	449+00	16.0	H + 5.0	2.5	5.0	1.5	5.0	40.0	60.0

- Design nail length for different wall sections with various heights may use this formula: L = H + 5.0 feet, where H is the maximum wall height for specified section.
- The locations of the top row of nails may be modified in some sections of the wall to accommodate for the drainage ditch above the wall. However, those sections are not clearly identified at this time. This office will modify and provide information on the locations of the nails, the test nails, and the test forces when we receive the wall elevation plans.

Table 4: Safety Factors for Proposed Soil-Nail Walls

Wall Nos.	Stations	Stations	Wall Data				Static (Global)	Pseudo-Static (0.15 g)
	From	To	Existing Slope (H:V)	Max H (ft)	Vertical Spacing (ft)	Horiz Spacing (ft)	Minimum S.F.	Minimum S.F.
RW372	372+00	374+50	1.5: 1	20.0	5.0	5.0	1.52	1.28
RW446	446+00	449+00	1.5: 1	16.0	5.0	5.0	1.50	1.28

Construction Notes:

- Nails are laid in checkered positions when there are two or more layers of nails.
- Nails are inclined at 15 degrees down from horizontal.
- All nails have a minimum diameter of 1.13 mm (#9 bar).
- Nails are to start at no more than 1.5 feet from the wall ends.
- Geocomposite drains should be installed vertically between the nails.
- Test nails are sacrificial and are at least 2 test nails per row.
- Each lift for vertical cut shall not be over 5.0 feet.

Construction Considerations for Soil-Nail Walls

Drilling for nail installation may encounter caving due to gravelly, sandy materials of the existing embankment. Caving and sloughing of the face materials may also be encountered during the first lift excavation and top row nail installation.

In areas where top rows of nails are close to the top of the cut, a short casing may be required for nail installations. The short casings, if necessary, are anticipated to be from 1.0 to 1.5-m long, and placed at the beginning of the holes.

The recommendations contained in this report are based on specific project information regarding structure support locations that have been provided to Office of Geotechnical Design – South 2. If any conceptual changes are made during final project design, Office of Geotechnical Design, Branch C, should review those changes to determine if the foundation recommendations contained in this report are still applicable.

If you have further questions, please contact Chris Hoadley at 916-227-4515 or Shawn Wei at 916-227-5252.

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